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**INNOVATION POLICIES FROM THE “INDUSTRY 4.0”
PERSPECTIVE: THE CASE OF CHINA**

Master’s thesis

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I declare that I have compiled the paper independently and all works, important standpoints and data by other authors have been properly referenced and the same paper has not been previously been presented for grading.

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Abstract

After decades of rapid development, China has already established a complete and independent industrial system, which has effectively promoted the process of industrialization and modernization, significantly enhanced the overall national strength and secured China's international position. In order to catch the current trend of "Industry 4.0" which was pioneered by Germany, China has put forward the "Made in China 2025" project in order for transforming and upgrading the current manufacturing industry. The current thesis presents the analysis of the "Made in China 2025" project. The results of the analysis indicate the likely consequences that the project would bring and the risk factors that may determine its final success. At the same time, several potential policy recommendations have been provided.

Keywords: Innovation Policy, "Industry 4.0", China, Manufacturing Industry, "Made in China 2025", Policy Analysis

List of Acronyms

ICT	Information and Communication Technologies
CPS	Cyber-physical System
R&D	Research and Development
S&T	Science and Technology
NIS	National Innovation System
OECD	Organization for Economic Co-operation and Development
DFKI	Research Center for Artificial Intelligence (Germany)
BMBF	Federal Ministry of Education and Research (Germany)
IoT	Internet of Things
IoP	Internet of People
MIIT	Ministry of Industry and Information Technology (China)
CNP	Comprehensive National Power
BRI	Belt and Road Initiative
SME	Small and Medium Enterprises
PPP	Public-Private-Partnership
BMAS	Federal Ministry of Labor and Social Affairs (Germany)
GDP	Gross Domestic Product
FDI	Foreign Direct Investment

1. Introduction

During the past few years, the global economy has experienced several financial crises and economic declines, which have changed the previous situation of prosperity and growth in the early 21st century. Even though a large number of developed countries have already overcome the negative economic growth through various approaches after suffering from the shock of the financial crisis, the recovery is still proceeding relatively slowly, and the global economy is lacking the impetus for growth. Under such background, the leaders of the world's major economies have generally agreed that only by carrying out technological innovation will it be possible to inject more vitality into the global economy and create more benefit for the people worldwide. Thus, various countries have put forward their own strategies and initiatives for the future development of science and technology.

In April, 2013, the final report of the German “Industry 4.0” Working Group was delivered to the press during the Hannover Messe (Hannover Industrial Fair) - one of the biggest industrial shows in the world. The report encompasses a whole series of innovative processes and developments that combine new technologies with industry standards in the manufacturing sector in order to serve the increasingly fast-moving markets and at the same time the report announced the beginning of the 4th industrial revolution (or the era of “Industry 4.0”).¹ Similarly, Perez (2010) has argued that the period of the deployment of information communication technologies (ICT) is currently under way according to the technological trajectory. As could be read from the content of this report, “Industry 4.0” has stressed the leading role of ICT and the application of cyber-physical system (CPS), which have been considered as the unavoidable trend of transformation in the current manufacturing industry worldwide. The report has gained attention worldwide and some countries have also made their own development proposals for manufacturing industry in order to follow this important technological trend. In 2015, the Chinese government put forward the “Made in China 2025” document, which could also be considered as the core supporting strategy that concentrates on

¹ Securing the future of German manufacturing industry Recommendations for implementing the strategic
Accessible: http://www.bmbf.de/pubRD/Umsetzungsempfehlungen_Industrie4_0.pdf

the Chinese manufacturing industry. “Made in China 2025” project consists of a series of innovation policies, which focus on the development of high-end manufacturing sector in order for China to achieve its transformation from the former manufacturer of quantity towards one of quality.²

According to its content, the “Made in China 2025” project has been influenced by the ideas of “Industry 4.0” to a large extent, for example it also has similar focus on the intelligent manufacturing and has also considered the CPS as the basis for promoting the further transformation in the current manufacturing industry. Although the final goals are similar and similar supporting policies as well as government initiatives are being implemented, under distinct political environment as well as economic background the preliminary results are significantly different. Compared with other developed countries with longer history of industrialization, China has a relatively weaker industrial foundation and lower degree of economic marketization and openness. Therefore, the digital transformation of the manufacturing industry in China is still under slow speed and tortuous process of growth and at the same time China is facing unprecedented challenges on its development (Ren 2015).

Since “Made in China” has been a hot topic for a long while, some scholars have already shown their interests on the development of Chinese manufacturing industry in the context of “Industry 4.0” and various related scholarly works from different perspectives could be found (see Hartmann et al. 2015; Zhou 2015; Wübbecke et al. 2016; Li 2017). Also, countless articles that are related to “Industry 4.0” or digital transformation with different research focuses are available (see Hofmann and Rüsçh 2017; Kiel et al. 2017; Stock and Seliger 2016). Basically, the existing studies concentrate on the interaction between different actors, technical standards, case studies on specific industries, etc. Until now, studies of the “Made in China 2025” strategy and its related policy initiatives under the background of “Industry 4.0” with a specific focus on analyzing the related innovation policies from an ex-ante perspective have not been published though. Thus, the aim of this thesis is to fulfill this gap in the wide range of the existing works.

² Made in China 2025, Ministry of Manufacturing and Information Technology (MIIT).
Accessible: fgw.chuzhou.gov.cn/download/58d37c0fe4b07e877d1ee5b3

The current thesis will therefore attempt to provide the ex-ante analysis of “Made in China 2025” project and its related policy initiatives based on the 3-dimension (supply side, demand side, and environmental side) innovation policy framework that was put forward by Rothwell and Zegveld (1981,1984), and theories of public policy analysis. By doing so, it will be possible to answer the following questions:

- How could the key policy initiatives within the “Made in China 2025” project be categorized in light of the innovation policy framework and in comparison to the “Industry 4.0” project in Germany, and what are the likely implications of the policy mix adopted in China?
- What are the likely benefits and consequences that the “Made in China 2025” project would bring to China for the manufacturing industry as well as economy and the risk factors that will influence its final success?

In terms of research strategy, the case study approach will be adopted in order to analyze the current situation and likely impacts of related innovation policies in China. By doing this, the current thesis will be able to open up the possibilities for further research and establish more concrete hypotheses. With regard to the research methods, the study will rely on qualitative methods such as content analysis as well as exploratory-evaluative research in order to understand the current status of the strategy and what have been achieved so far. This would be helpful for illustrating the potential consequences of the related policies. As for the data and sources, the current thesis will be based on qualitative data and will rely on secondary sources as well.

The rest of the thesis will be structured as follows. The methodology part provides a more detailed description of the research design. The theoretical framework will concentrate on the key content of innovation as well as innovation policy and the theories of public policy analysis. Based on the theoretical framework, the empirical research will then present a case study of Chinese innovation policies in the context of “Industry 4.0”. The basic idea of the empirical research is to provide the opportunity to have an overview of the undergoing project and to answer the two proposed research questions. Minor policy recommendations will also be put forward in the empirical part on the basis of the analysis of related policies. And finally, the conclusion part will focus on summarizing the primary findings.

2. Methodology

In the current thesis, innovation policies that are related to “Industry 4.0” in China would be investigated in-depth and the aim of this methodological part is to explain how the policy data in China will be collected and analyzed.

In general, the relevant policy data that are collected in current thesis for the empirical analysis are from government reports, newspapers, journals, diplomatic messages as well as the publications of various related ministries. However, in order to secure the accuracy of the analysis, the current thesis will primarily rely on the official policy documents that are published by the Chinese government. In China, after the announcement of “Made in China 2025” strategy, the “1+X” supporting documents (see Appendix 1) have been published in 2017 and China’s basic “Industry 4.0” policy framework has therefore been built up. By reviewing the relevant policy documents, it would be possible to provide the foundation for the following policy analysis. Based on the 3-dimension innovation policy framework by Rothwell and Zegveld (1981,1984), the author will firstly research the policy landscape and construct a policy framework of the “Made in China 2025” project in comparison to the “Industry 4.0” project in Germany. Based on the theories of public policy analysis, the author will then attempt to address the likely consequences, the strengths and weaknesses of the project in order to answer the two proposed research questions.

For answering the proposed research questions, qualitative research methods such as case study, content analysis and exploratory-evaluative research have been selected according to the following reasons. According to Merriam (1988), instead of hypothesis testing, qualitative research concerns about discovery, understanding and interpretation, which is in line with the actual intentions of the case study in current thesis. Yin (2003) has categorized the research questions in the social science field as *explanatory*, *descriptive*, and *exploratory*. Van Thiel (2014) argued that the analysis of “*what*” questions are basically exploratory, the “*who*” and “*where*” questions shall be descriptive, whereas the “*how*” and “*why*” questions are likely to

be explanatory. The research questions in current thesis are basically “*what*” questions, thus the exploratory-evaluative case study will be conducted.

The author believes that the above selected research methods would be helpful to gain an in-depth picture of the policy initiatives of the “Made in China 2025” project and will provide a better understanding of the innovation policies under the background of “Industry 4.0”. Therefore the above methods would make it possible for the author to answer the proposed research questions based on the empirical findings and at the same time provide several potential policy recommendations.

3. Theoretical Framework

Before carrying out the empirical research and discussion, one needs to present the major theoretical bases that are related to innovation, innovation policy, and public policy analysis. In this case, this section will attempt to demonstrate a synthesis of relevant concepts and theories based on various scholarly works.

3.1 Innovation

The idea of innovation has been considered as a critical element in the development process of the global economy. As one of the most famous pioneers of the innovation studies, Joseph Schumpeter (1934) has defined innovation as the kind of activities that aim at developing the already-invented element into the commercial-useful element which could at the end be accepted in the social system. Other scholars have also put forward definitions of innovation from their perspective. Afuah (1998) considered innovation as the combination of various new knowledge in order to provide new products or new services to the customers. Kanter (1988) argued that innovation should include original invention and creative usage and he also considered innovation as the generation, admission and realization of new ideas, new products, new services and new business processes.

One should also understand that a whole series of relevant aspects would be involved in the innovation process along with various stakeholders including science and technology, organizations, finance as well as commerce. Innovation would be able to occur everywhere, in developed countries as well as developing countries, in service industry as well as manufacturing industry, in both public sector as well as private sector (Fagerberg et al. 2010; Rubalcaba et al. 2012). It is also believed by many scholars that innovation is currently one of the major forces in economic growth (see Schumpeter 1934; Rosenberg 2004; Wong et al. 2005). Thus, countries that would like to promote their economic development and enhance the comprehensive national power (CNP) should not ignore the important role of innovation.

3.2 Innovation Policy

Innovation policy is one of the key factors that determine the quality as well as efficiency of innovation activities. Some may consider that all the policies that may have impact on innovation activities could be seen as innovation policies. However, the concept of innovation policy could also be defined in a narrow way. Edquist (2004) argued that only when the policies are created with the intention to have influence on innovation should be considered as innovation policy. Innovation policies could basically be classified as supply-side-oriented or demand-side-oriented (Edquist and Hommen 1999). And, as it is believed by the policy researchers, the innovation policy shall be an interaction that combines science and technology (S&T) policies and industrial policies; the main focus of innovation policy would be the overall innovation performance and the economic impact (Rothwell 1986; Lundvall and Borrás 2005). In general, the analysis of innovation policy shall be qualitative and descriptive according to various scholarly works. Kirschen (1964) has firstly introduced the idea of the tools of innovation policy and has therefore categorized the innovation policies into 64 different policy tools. After that, Schneider and Ingram (1990) have attempted to make different categories for policy analysis, in which authority tools, capacity tools, symbolic tools and hortatory tools as well as learning tools have been included.

The concept of National Innovation System (NIS) has been widely applied for the analysis of innovation policy in various countries. The idea of NIS could be traced back to the previous works of Freeman (1987, 1995), Lundvall et al. (1988, 1992) as well as Nelson (1993), which have been published during 1980s and 1990s. Freeman's (1987, 1995) work focuses on the social-political institutions among the innovation process. He considered the NIS as the network of various institutions in public sector as well as in private sector whose activities and interactions would be able to initiate, import, and diffuse the new technologies. Lundvall (1992) has researched the idea of NIS in-depth based on the concept of "national production system" which was put forward by Friedrich List (1841) and the theory of "informal technical collaboration among firms" that was proposed by von Hippel (1982). According to Lundvall (1992), NIS shall be seen as the constitute by elements and relationships which interact in the production, diffusion and usage of new, economic-useful knowledge. Similarly, Nelson (1993) has defined the NIS as a set of interacted institutions that could determine the innovation performance of national enterprises. Thus, one could conclude that NIS is in

general indicating the interactive system of existing institutions, which would include firms (both state-owned and private), educational institutes such as universities and colleges, and various government agencies. The main purpose of NIS is to put forward, promote and enhance the S&T and innovation activities within the national borders. According to Niosi et al. (1993), the interactions among the institutions of NIS would therefore focus on the technical, commercial, legal, social as well as financial part; the main approaches shall cover R&D, fiscal support (direct and indirect), and S&T related regulations. Figure 1 shows the main elements as well as their interactions in NIS which would be able to improve the innovation performance of the country according to OECD (1997) report. As a result, the performance of innovation in each country will rely on how these elements would interact with each other to a large extent.

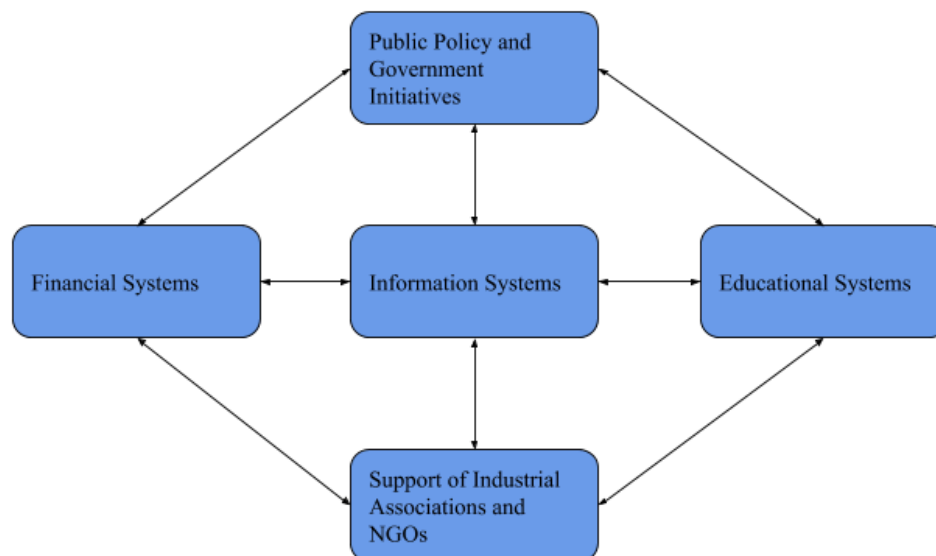


Figure 1. The main elements and their linkages in NIS

Source: OECD 1997

Till now, various scholarly works that analyze the innovation policies based on the framework of NIS could be found; and as could be read from their content, the NIS framework has been applied to the analyses of innovation policies in both developed countries and developing countries (see Mowery 1998; Intarakummerd et al. 2002; Zhong and Yang 2007). Indeed, NIS is a rational method for analyzing the innovation policies in different countries since it would be able to cover various relevant institutions and their interactions. However, as the current

thesis will focus on the content of a single national strategy with various policies rather than the interaction between different involved actors, a more classification-oriented innovation policy framework would be adopted in order to establish a policy framework of “Made in China 2025” project as the foundation for the further analysis.

The research of Rothwell and Zegveld (1981, 1984) has concluded 3 dimensions with 12 innovation policy tools, which has provided a concrete policy analysis approach for the innovation development at national level. In their studies, innovation policies have been summarized into 3 different categories including supply side policies, which affect industrial innovation and development by introducing R&D activities; demand side policies that aim at creating market for the innovation development; and environmental side policies which would influence both the supply as well as demand side by building up related infrastructures. On the supply side, the R&D of new products and new business processes shall be dependent on the inputs of related initiatives such as providing direct support on S&T, improving the quality of education in order to provide qualified labor force, providing information about potential market, management skills and required knowledge in order to ensure the effectiveness and efficiency of R&D process. On the demand side, the government tends to focus on raising the demand of innovation activities in both domestic market as well as international market. For example signing central or local government purchase contracts, establishing oversea agencies of innovative enterprises, etc. On the environmental side, the government is responsible for adjusting the general environment and infrastructure, under which the innovation activities would take place, for example, legal requirements and regulations, financial and taxation framework, investment environment, etc.

As has been argued by other scholars, a successful innovation in industry will rely on the combination of technical supply, market demand as well as overall innovation environment (Allen et al. 1978; Freeman 1979). Thus, it is reasonable to undertake a further analysis after the classification of the related innovation policies of “Made in China 2025” project into the above-mentioned three categories.

This framework has been widely used when carrying out policy analysis as a foundation together with other public policy analysis theories (see Loiter and Norberg-Bohm 1999; Norberg-Bohm 2000; Shyu and Chiu 2002; Lin et al. 2013). The following Table 1 that

simplifies and summarizes the work of Rothwell and Zegveld (1981,1984) has shown the 3 policy categories with relevant policy tools and will attempt to classify the policy tools that would affect industrial innovation.

Policy Dimensions	Policy Tools	Policy Classification
Supply Side	Public Enterprise	Innovation activities by state-owned enterprise; Establishing new industries; Applying new technologies by public enterprises; Cooperation with private firms; etc.
	Science and Technology	Establishing research laboratories and R&D centers; Supporting S&T research associations; Providing research grants; etc.
	Education	General education; Universities and colleges; Vocational education; Apprenticeship program; etc.
	Information	Establishing information platform; Providing consultancy and advisory services; Establishing related database; etc.
Environmental Side	Financial	Providing loans, subsidies, financial sharing arrangements; Optimizing the financial mechanism; etc.
	Taxation	Adjusting company, personal, and payroll taxation systems; Offering tax relief arrangements; etc.
	Legal and Regulatory	Optimizing the existing legal framework; Adjusting the related regulations; etc.
	Public Sector Reform and Innovation	Political reform; Regional policies; Public consultation; Innovation activities in public sector; etc.
Demand Side	Public Procurement	Central or local government purchases and contracts; Technology transaction through public procurement; etc.
	Public Services	Purchase, maintenance, supervision, and innovation in various related public services such as transportation and telecommunication, health, banking, etc.
	Commercialization	Trade agreements; Commercialization and industrialization of innovation products; Currency regulations; etc.

	Overseas Agents	Overseas representation for international business and trade; Establishing official organizations in support of the internationalization of innovation products; etc.
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Table 1. Policy tools in the 3-dimension innovation framework

Source: Author’s elaboration based on the works of Rothwell and Zegveld (1981, 1984)

The author believes that by categorizing the involved policy initiatives in “Made in China 2025” project according to this innovation policy framework in comparison to Germany’s “Industry 4.0” project, it would be able to provide the foundation for further empirical analysis that aims at answering the proposed research questions.

3.3 Policy Analysis

To understand the content of the selected project at policy level is not an end. On the contrary, the current thesis is also aiming at figuring out the likely benefit as well as consequences that the project would bring and the risk factors that may determine its final success. In this case, the theories of public policy analysis with specific focuses on policy outcome forecasting as well as evaluation will also be reviewed as the “lenses” for the later empirical research.

Policy analysis is a kind of social science technique that is usually used in public administration, aiming at solving problems. The understanding of policy analysis varies based on different perspectives. Williams (1971) considered policy analysis as a means of synthesizing information to produce a format for policy decision-making and of determining the future needs for policy relevant information. Dunn (1981, 2004) defined policy analysis as an applied social science discipline that would use multiple approaches of inquiry as well as argument to produce and transform policy-related information which can be utilized in political settings to resolve policy problems. The studies of Weimer and Vining (2017) put this concept in a more client-oriented way, as they argued that the policy analysis should result in the advices that are related to public decision and informed by social value. In their opinion, a good policy analysis should have a comprehensive view of the likely consequences and the social values. Although the definitions of policy analysis are distinct, in general, the

policy analysis shall involve evaluating the issues of public importance and providing empirical facts as well as statistics about the extent and the impact of various policy initiatives.

Policy outcome focuses on what kind of influences the selected policies would be able to have. According to various scholarly works in the field of policy analysis or assessment, one could see that by evaluating the policy outcomes, policy-makers or researchers would easily understand how to adjust the current policies (see Dunn 2004; Böhringer et al. 2009; Huang 2016). Rossi et al.'s (2003) theory of program evaluation, which includes program process evaluation and program outcome evaluation, could also be used for analyzing public policies. They consider the outcome evaluation as an important tool for understanding the consequences of a selected program. Outcome evaluation would focus on outcome level, outcome change, and program effect, which would be able to measure the status of outcome that would be gradually changed and their impact on the program. At the same time, outcome evaluation would also rely on different indicators, which should involve variables that the program is expected to affect (*Ibid.*). Dunn (2004) has also argued the importance of forecasting policy outcome through different approaches including trend extrapolation, theoretical assumptions, and informed judgments. He considered the forecasting of the likely impact as an effective method on providing practical information about the future changes in public policies as well as their consequences and helping the policy-makers to understand, to control and to optimize the current policies. For the analysis of the likely benefit as well as consequences, the empirical data as well as the related theories shall play the central role (*Ibid.*).

The achievement of policy outcome would also be influenced by various risk factors, which would not only affect the policy implementation but also will be able to determine its final success. The evaluation of the risk factors should also be seen as the key part for analyzing public policies, which shall focus on the assessment of various risk factors that may exist in the current public policy system (Zhu et al. 2015). In the public policy system, risks would run through the entire policy process: the origin of the risks may either be the failures during the policy formulation or the failure during the policy implementation; it may come from the policy system or from the policy environment. Thus, the evaluation of the risk factors should be carried out from a comprehensive perspective and should concentrate on the entire public policy system (*Ibid.*).

The selection of risk factors should also be taken into account when carrying out related analysis or assessment. According to various scholarly works, the factors that could determine the effectiveness of specific public policies tend to cover political environment, economic status, social structure, etc. (see Berman 1977; Yan 2002; Makinde 2005). Therefore, for analyzing the risk factors of public policies, different focuses should be covered since the political environment, economic as well as social status vary in different countries. Empirically, it is also possible to have risk factors that would only exist in specific countries (see Hunter 1973; Yang 2015). At the same time, the selected risk factors for analysis should also be supported with empirical evidences (see Wübbecke et al. 2016; Kiel et al. 2017; Li 2017). Besides, as argued by Huang (2017), the goals that have been set up for the policy or public project shall also be seen as one of the potential risk factors. Over-ambitious goals without considering the actual conditions would sometimes lead to unsatisfied results as she has expressed in her work on analyzing the BRI project (*Ibid*). Similarly, Leenes's (2004) research on the e-government project in Netherlands and Aminuzzaman's (2010) work on the environment policy of Bangladesh could also support this argument. In addition, there would also be other risk factors that could affect the result of the public policy or public project in terms of the implementation efficiency and capability, which including coordination issues (Brinkerhoff 1996), human resources issues (Liebowitz 2012), and funding problems (Taylor and Fleming), etc.

In order to carry out a successful policy analysis, suitable approaches shall be selected. The current research objective, as mentioned before, is a national strategic project that has targets up to 2025. Till now, the relevant policy initiatives have been implemented for no more than 3 years. Although those policy initiatives may have already had some impacts on the manufacturing industry, economy, or the social structure, it seems to be too early to measure the overall policy performance at this moment. However, one could still discover the likely benefits as well as consequences that the project would bring and the risk factors that would influence the final success of the project. Therefore, an ex-ante approach for policy analysis shall be selected. An ex-ante approach for policy analysis is to forecast the potential effects of the policy initiatives and make it possible for policy-makers to make adjustment on the current policy mechanism. Although it has often been used in business analysis, in recent years it is also becoming a popular method for analyzing the new policy or new public project

(see Feldman and Kelley 2006; Helming et al. 2011; Mostafavi et al. 2013). Based on the outcome evaluation theories, an ex-ante analysis will be able to forecast the potential impact that the related policies will bring on the industry, economy or society based on the relevant data and empirical results.

4. Case of “Made in China 2025” Project

4.1 Overview of Chinese Manufacturing Industry and the Concept of “Industry 4.0”

Each country has its own history of manufacturing industry, but at the same time manufacturing industries tend to play different roles in different countries. Since the middle of the 18th century when the industrialization began, the world history has gradually confirmed that manufacturing industry is one of the key sectors that would have huge influence on economic growth as well as national stability. In this light, the following section will provide a brief introduction about the history and current status of Chinese manufacturing industry. The concept of “Industry 4.0” will be involved in this part as well.

In China, the manufacturing industry has experienced a tortuous history of development. The industrialization process in China officially started in 1953 when the “First Five Year Plan” was implemented, which was relatively late compared with other developed countries. However, since then the Chinese manufacturing industry experienced rapid growth, especially after the implementation of the “Reform and Opening-up” policy in 1978. Till now, China has already established a complete and independent industrial system, which has effectively promoted the process of industrialization and modernization, significantly enhanced the overall national strength and secured China’s international position. According to the statistics, Chinese manufacturing industry has shown a stable growth during recent years and has continually provided job opportunities. In 2017, the gross industrial output accounted for 36.9% of the GDP in China and has increased by 6.9% as compared with 2016.³

However, compared with other developed countries that have much longer history of industrialization, there is still huge gap in terms of the capability of independent innovation, efficiency of resource utilization, basic industrial structure, etc. Currently, China should actually be seen as a world production center rather than an international manufacturing

³ Statistics from National Bureau of Statistics, 2017

power. There are many problems and issues which are challenging the development of Chinese manufacturing industry such as raising labor cost, irrational resource consumption, environmental damage, etc. Also, affected by the de-industrialization actions in some countries, China is also facing the problem that the financial economy is eroding the manufacturing industry (Lin et al. 2017). Thus, there is an urgent demand for the transformation and upgrading in current manufacturing industry.

“Industry 4.0” is a set of technological changes in current manufacturing industry and has set up a coherent policy framework in order to maintain the global competitiveness of German manufacturing industry. “Smart factory” is the key concept of “Industry 4.0”, in which the cyber-physical system (CPS) will be used for monitoring the processes of physical production in the factory and at the same time make it possible to have a decentralized decision-making process (Hartmann et al. 2015; Kiel et al. 2017; Hofmann and Rüscher 2017). “Industry 4.0” is expected to transfer the traditional manufacturing plant to a highly flexible as well as reconfigurable manufacturing system by implementing the idea of “smart factory (Zhang et al. 2015; Stock and Seliger 2017). As the “Industry 4.0” report has indicated: “the future manufacturing systems will be vertically networked with the business processes within the factories and enterprises and horizontally connected to spatially dispersed value networks that can be managed in real time – from the moment an order is placed right through to outbound of the logistics” (BMBF 2013).

The ideas of “Industry 4.0” have been adopted into the public policies for the countries worldwide. After Germany has provided the concept of “Industry 4.0” which stresses the establishment of “smart factories” based on the application of CPS and promoting the industrial-academic cooperation, other countries have also put forward related strategies and policies. The US has launched the “Advanced Manufacturing Partnership” program, in which 2.2 billion USD have been invested in order to promote the reindustrialization process.⁴ In Japan the “Industry Revitalization Plan” which focuses on the development of robotic technology in order to increase the efficiency and added value of production has been put forward.⁵ In China, the white paper of “Made in China 2025” project has launched in order to

⁴ Accelerating U.S. Advanced Manufacturing, released in 2014.

Accessible: https://www.manufacturing.gov/sites/default/files/2018-01/amp20_report_final.pdf

⁵ Japan Revitalization Strategy, revised in 2014

Accessible: <https://www.kantei.go.jp/jp/singi/keizaisaisei/pdf/honbunEN.pdf>

catch the current trend of smart manufacturing and China is expected to be a new global innovation hub according to its plan.⁶

4.2 Empirical Research

4.2.1 Policy Framework of “Made in China 2025” Project

In 2015, the official document of “Made in China 2025” project was published under the direction of the Ministry of Industry and Information Technology (MIIT) in face of the era of “Industry 4.0”. The aim of this project is to optimize the current Chinese manufacturing industry according to the ideas that were adapted from Germany’s “Industry 4.0” strategic project in order for China to achieve the successful transformation and upgrading from the former “manufacturer of quantity” to the “manufacturer of quality”.

The document has announced 9 key strategic tasks:

- Improving the ability of innovation in the manufacturing industry;
- Promoting the deep integration of ICT and industrialization;
- Strengthening the basic industrial foundation;
- Strengthening the establishment of international qualified brands;
- Implementing the idea of "green manufacturing";
- Promoting the technical breakthroughs in the focused areas such as ICT, robotics, aerospace equipment, marine engineering equipment, biomedicine, etc.;
- Promoting the structural adjustment of the current manufacturing industry;
- Developing the service-oriented manufacturing industry as well as productive service industry;
- Improving the international level of current manufacturing industry.

In 2017, 11 supportive policy documents ("1+X") that based on the "Made in China 2025" strategy were published by MIIT with focuses on smart manufacturing, green manufacturing, high-end equipment, etc. (see Appendix 1). The documents are aiming at securing the stable industrial growth and promoting the industrial transformation and upgrading. According to the plan, China is expected to become a world power of advanced manufacturing by the year of 2025. This section will firstly classify the related policies according to Rothwell and

⁶ Made in China 2025, Ministry of Manufacturing and Information Technology (MIIT)
Accessible: fgw.chuzhou.gov.cn/download/58d37c0fe4b07e877d1ee5b3

Zegveld's (1981, 1984) 3-dimension policy framework in order to understand the key policy initiatives that have been involved.

- Supply Side Policies

On the supply side, related policies focus on enhancing China's national manufacturing innovation capability as well as the basic industrial capacity, and at the same time the government is also engaged in completing a multi-level talent education system. The key actors that have been involved are basically the Ministry of Industry and Information Technology, the Ministry of Education, various manufacturing enterprises, and universities as well as research institutes in China. One could notice that China is now gradually becoming an "entrepreneurial state" according to Mazzucato's (2011) theory since the public sector has really participated in the innovation process and has become one of the most important actors. Instead of making up the market failure, the government should be considered as the leading agent in achieving innovative goals as well as driving economic growth in China (Lu 2017). A large amount of the innovation activities in China are carried out directly by the government or under various government supports.

According to the policy documents, the key initiatives under this category are as follow. Firstly, improving the cooperation between public sector, research and educational institutes, and enterprises by establishing R&D centers, science parks as well as technical training centers, providing large amount of financial grants, and carrying on public funded research projects with specific focuses. Secondly, applying an environmental-friendly model of manufacturing industry and reducing the pollution. Thirdly, enhancing the quality of current education system at all levels including primary education, higher education, vocational education, apprenticeship program, etc. Fourthly, establishing relevant information database, evaluation system of industrial talent and information distribution platforms.

The above initiatives are expected to have positive influences on improving the technical standard, providing the manufacturing enterprises with qualified talent and labor force as well as practical information, implementing the idea of "green manufacturing". However, the policy initiatives towards public enterprises are missing. Due to the historical reasons and national conditions, the state-owned enterprises have taken up a large proportion of the entire manufacturing industry in China. Especially in the following industries, such as petro chemistry, metallurgy, electronics, automobile, etc., state-owned enterprises are performing

the role as the key pillar (Lu 2017). Therefore, the roles that public enterprises would play during the current digital transformation in Chinese manufacturing industry should not be ignored. Detailed policy initiatives, which concentrate on public enterprises, are lacking though.

- Demand Side Policies

As according to Rothwell and Zegveld (1981, 1984), the demand side policies are expected to have positive influences on both domestic as well as international market and in the end they should also help to improve the country's innovation performance. On the demand side, the "Made in China 2025" project has set up several goals: to support the commercialization of innovation achievements and to enhance the brand quality construction, to provide high-quality public services in support of the current digital transformation and upgrading in Chinese manufacturing industry, and to render the Chinese manufacturing industry more open to foreigners. The key actors that have been involved are the Ministry of Industry and Information Technology, the Ministry of Commerce, and a large number of manufacturing related enterprises.

According to the strategic white paper and its supporting documents, the key initiatives under the demand side policy category are as follow. Firstly, in combination with the "Belt and Road Initiative" (BRI), cooperation between local and foreign enterprises is encouraged by establishing representative offices, manufacturing plants or R&D center, at the same time international exchange between the technical specialists from different countries will be supported by government. Secondly, the government is taking effort on improving the quality of Chinese manufacturing products by offering technical support, enhancing the product quality supervision mechanism as well as brand construction, optimizing the intellectual property protection, etc. Thirdly, more qualified public services will be provided in order to assist the transformation, especially concentrate on education, R&D, SMEs and international cooperation. Lastly, various public procurement projects on innovation products have been carried out and the government is also trying to optimize the mechanism of public procurement.

Based on the above policy initiatives that are summarized from the policy documents, one could notice that all the 4 policy tools on the demand side including establishing oversea agents, commercialization, public services, and public procurement have been covered. Those

demand side policies are expected to affect the situation of Chinese manufacturing products in both domestic and international market.

- Environmental Side Policies

Rothwell and Zegveld (1981, 1984) have argued that the role of environmental side policies is to provide an innovation-friendly environment for industrial innovation through several related policy instruments including financial policies, taxation, political environment, legislation and regulation. As for the current Chinese case, the goal of Chinese government on the environmental side is to adjust the overall environment in China where the innovation activities shall take place. The key actors that are involved are the Ministry of Finance, the State Administration of Taxation, and the Ministry of Justice.

As could be read from the policy documents of “Made in China 2025” project, following policy initiatives shall be considered as the key focuses. Firstly, financial system in China is under the transformation to more open and market-oriented. Through the Public-Private-Partnership (PPP), social capital⁷ is encouraged to participate in the construction of main manufacturing projects, the technological transformation of enterprises, and the construction of key infrastructure. In cooperation with financial institutions, integrated financial services such as loans, bonds and leasing shall be provided to the manufacturing enterprises. Secondly, the taxation system is also under transformation in order to serve this project. Tax reduction on R&D and high-tech manufacturing products will therefore be implemented and for products with high pollution and high energy consumption as well as some high-end consumer goods the tax rate shall be increased. Also for the products that have high added value, high-technology content, independent domestic brands, etc., the zero-tariff policy will be implemented on the export and the rate of export tax rebate will be increased as well. Lastly, the optimization of the current legal system is also undergoing in order to promote the product quality control as well as intellectual property protection that have also been mentioned in the demand side policies.

The above policy instruments are expected to affect the overall environment for the digital transformation and upgrading of the Chinese manufacturing industry through financial policies, taxation and legal approaches. However, there are certain deficiencies in the government function in China such as the ineffective supervision on the market, lacking

⁷ Non-government financial investment

cooperation between central and local governments, etc. (see Wübbecke et al. 2016; Feng 2016; Zhang 2017). Those could have negative effects on the implementation of the “Made in China 2025” project and impeding the achievement of the proposed goals of the project. Related signs such as irrational investment of local governments and misallocation of public funds have already occurred (Feng 2016). Therefore, the adjustments of the overall political environment are also important. However, the policy documents of the “Made in China 2025” project have not covered such kind of adjustments.

4.2.2 Comparison with German Project

Germany should be seen as the pioneer of implementing the ideas of “Industry 4.0” where similar project is undergoing. The following Table 2 summarizes the related key policy initiatives in Germany according to the official report of BMBF (2013, 2015) and the 3-dimension innovation policy framework by Rothwell and Zegveld (1981, 1984). Table 3 compares the related policy instruments that have been applied in China and Germany.

Policy Dimensions	Policy Tools	Key Policy Initiatives
Supply Side	Public Enterprises	Increasing R&D expenditure; Cooperation with universities and research institutes
	Science and Technology	Establishing R&D centers; Financial grant; Public funded research projects
	Education	Optimizing current multi-level education system; Promoting digitalized education
	Information	Improving information transparency; Establishing “Industry 4.0” information platform
Demand Side	Procurement	Public procurement projects on R&D products
	Public Services	Improving the quality and efficiency of public services
	Commercialization	Promoting commercialization process of scientific discovery
	Oversea Agent	Establishing oversea representatives, R&D center and manufacturing plants
Environmental Side	Public Sector Reform and Innovation	Reinforcing the cooperation between ministries, between central and local government; Promoting the digitalization in public sectors

	Taxation	Providing tax incentives for SMEs and innovative enterprises
	Financial	Offering effective financial supports
	Legal and Regulatory	Enhancing the data security; Optimizing the legal framework

Table 2. Related policy initiatives of “Industry 4.0” project in Germany

Source: Summarized from the reports of BMBF (2013, 2015)

Related Policy Instruments	China	Germany
Supply Side	Cooperation between government, enterprises, universities and research institutes; Financial grant; Multi-level education system; Information database	R&D expenditure in public enterprises; Cooperation between government, enterprises, universities and research institutes; Multi-level education system; Digitalized education; Information platform
Demand Side	Public procurement projects; Oversea activities in combination with BRI project; Commercialization of scientific discovery; Improving the quality and efficiency of public services	Public procurement projects; Oversea activities; Commercialization of scientific discovery; Improving the quality and efficiency of public services
Environmental Side	Tax incentives; Transformation and upgrading of financial system; Optimizing legal framework	Tax incentives; Effectiveness of financial support; Optimizing legal framework; Cooperation between public sector and organizations

Table 3. Comparison of related policy instruments in China and Germany

Source: Summarized from the reports of BMBF (2013, 2015) and MIIT (2015)

Indeed, “Made in China 2025” does not equal “Industry 4.0” since the national conditions in the two countries are distinct. However, from the above two tables one could be able to understand the similarities between the two projects in China and in Germany at policy level.

From their contents, the two projects are quite similar in terms of the involved policy initiatives. Both of the Chinese and German projects have covered all the 3 policy dimensions and basically all the 12 policy tools have been involved. As according to Rothwell and Zegveld (1981, 1984), ideally the country should cover all the 3 dimensions in order to effectively and efficiently support the innovation activities. However, even though China and Germany have used the similar approaches and both of them have concerned all the 3 policy dimensions, distinct results have been achieved. According to the report of PwC (2016), one-third of German manufacturing enterprises have already achieved advanced level of digitalization and are ready to enter the stage of “Industry 4.0”. Some enterprises such as Siemens, Volkswagen, etc. have already begun to take shape of “smart factory”. At the same time, in China the digitalization process is relatively slow and low-end manufacturing still occupies a large proportion.

According to the comparison, one is able to find that Chinese project has not covered policy initiatives towards public enterprises and public sector reform and innovation. Therefore, these could have effect on the implementation of “Made in China 2025” project to some extent. In the later policy assessment, based on the findings in this section, the author will therefore attempt to figure out the weaknesses and risk factors that have resulted in the current unsatisfied progress and may also affect the final success of “Made in China 2025” project.

4.2.3 Preliminary Assessment

To classify the related policy instruments is not an end, on the contrary, it would serve as the foundation for the further policy analysis. Based on the above policy framework that was summarized from the related policy documents of the “Made in China 2025” project and the comparison with Germany’s “Industry 4.0” project, one could notice that all the 3 policy categories as well as almost all the 12 policy instruments have been covered. Chinese government has taken steps to promote the upgrading of current manufacturing industry through various approaches. However, “Made in China 2025” is still a relatively new project that started in 2015 and its targets are set for 2025. Thus, it is too soon to assess the overall performance of the project at this moment. From now to 2025, many uncertain factors could affect the implementation of the related policy initiatives and the final success of the project. Nevertheless, one could still analyze the likely consequences that the project would bring based on empirical findings as well as related data. And, at the same time, it is also worth to

understand several risk factors that will influence the final success of “Made in China 2025” project.

4.2.3.1 Likely Consequences

In order to understand how the “Made in China 2025” project would affect the economy and society, the author has selected 4 indicators including industrial capacity, R&D, economic growth, and social structure for the following analysis since the above indicators shall be seen as the key elements that the project intends to make contribution to. At the same time, the selected indicators would involve variables that the project is expected to affect. Based on the preliminary results of the project implementation and various related data, it would be possible to forecast the likely consequences of the project and some important preconditions for achieving expected results. The used data for the following analysis are obtained from the World Bank and the National Bureau of Statistics of China. Based on the analysis of the likely consequences, it will also open up the further possibility for understanding the risk factors that may affect the implementation of “Made in China 2025” project.

- Industrial capacity

The implementation of “Made in China 2025” project has already had positive influences on enhancing the industrial capacity of China and Chinese manufacturing would gradually adapt the high-quality and stable development model. Since the project has been implemented under government initiatives and the cooperation of related enterprises, various industrial indicators are growing steadily. According to the statistics, the overall industry added value of industrial enterprises above designated size in 2017 has increased by 6.6% compared to the previous year, and the industry added value of the focused industries has even increased by 11%. Currently the rate of industrial capacity utilization is 77%, which has hit its highest record in the past 5 years. The overall profits of industrial enterprises above designated size have increased by 21.9%.⁸ At the same time, Chinese manufacturing industry has been under a progressive structural adjustment in recent years, from the previous low added value- and labor-intensive model to the high added value- and technology-intensive model. The investment in technical transformation has accounted for 44.6% of the total industrial investment.⁹ The following Figure 2 shows the overall industry added value in China from 2007 to 2017. Figure 3 presents the industrial capacity utilization in China from 2007 to 2017.

⁸ Statistics from National Bureau of Statistics, 2017

⁹ Statistics from National Bureau of Statistics, 2017

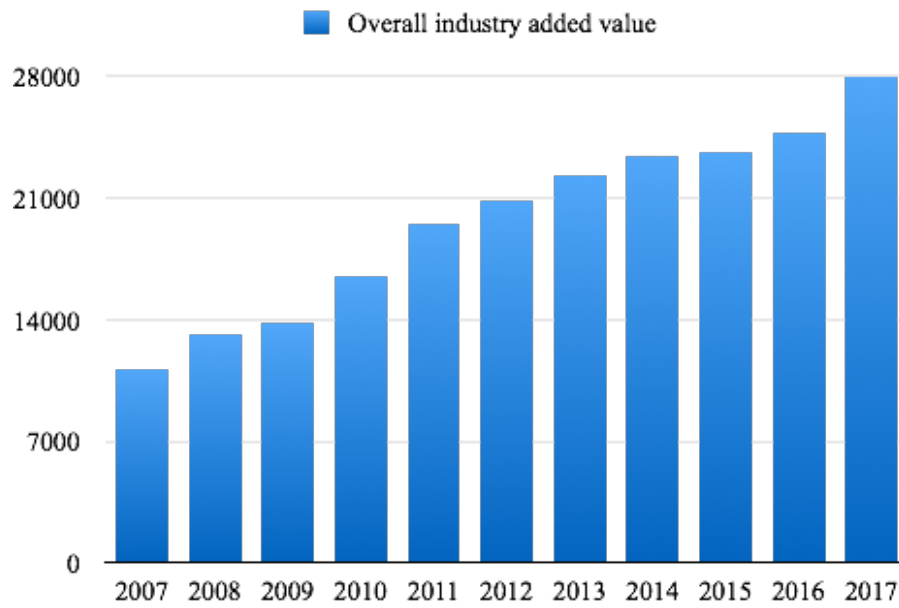


Figure 2. Overall industry added value in China from 2007 to 2017 (CNY, billion)

Source: National Bureau of Statistics

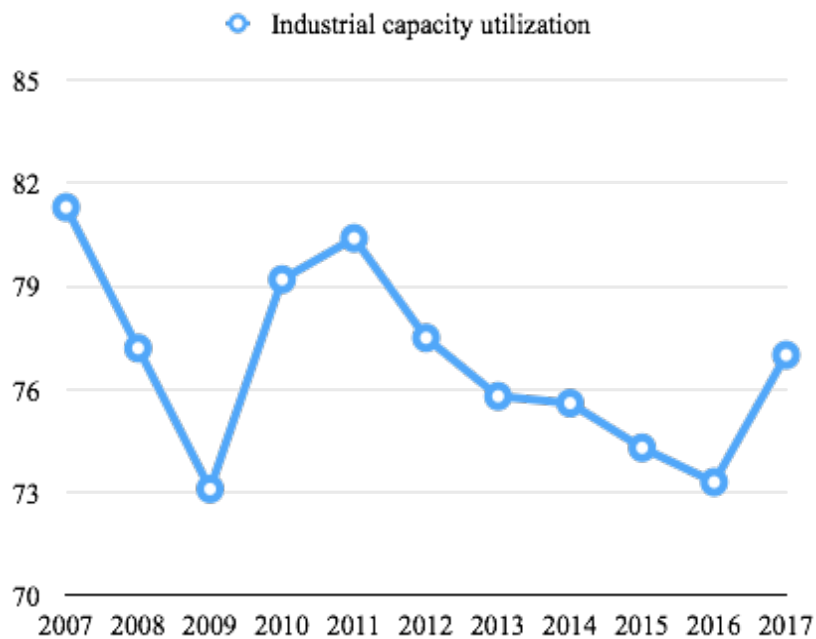


Figure 3. Industrial capacity utilization in China from 2007 to 2017 (%)

Source: National Bureau of Statistics

From the above data and figures, one could see that the implementation of the current project has already made a lot of contribution to the development of Chinese manufacturing industry.

If this project keeps undergoing according to the formulated policy initiatives, the industrial capacity of China will be improved dramatically and the waste of industrial resources could be avoided to a large extent. The gap between China and those developed countries with longer history of industrialization will be narrowed and also there will be more world famous Chinese manufacturing brands in the near future. In addition, the improved industrial capacity will serve as the foundation for the further digital transformation in China's manufacturing industry and make it possible to establish more "smart factories" in China according to the ideas of "Industry 4.0". However, as argued by the specialists from MIIT (2016), a certain degree of excess manufacturing capacity has already occurred in China, which has restricted the overall performance and upgrading of Chinese manufacturing industry. Thus, instead of enhancing financial support on manufacturing industry, intensifying the cooperation between government and enterprises, etc. as have been mentioned in the policy documents of "Made in China 2025" project, reducing the excess manufacturing capacity is also the important precondition for improving the overall industrial capacity in China.

If the "Made in China 2025" project would be successful, it could be forecasted that China will gradually become a "manufacturer of quality" rather than a "manufacturer of quantity", and China's manufacturing industry will gradually achieve its upgrading and digital transformation. However, it may also intensify the unbalanced regional development. While the first-tier cities such as Beijing and Shanghai are actively upgrading their manufacturing industry, those regions with weaker industrial foundation may find it difficult to keep up with the current trend. Related signs have already occurred according to the statistics from National Bureau of Statistics: after the implementation of the "Made in China 2025" project, the gap between first-tier cities and other cities in terms of GDP as well as high-tech industry output value has become wider.¹⁰ As suggested by Hasen (1965) and Wei (2001), unbalanced development in terms of industrial capacity would restrict the overall performance of the manufacturing industry of a country. Therefore, if this unbalanced trend of development keeps undergoing, it is very likely that only a part of the regions in China would share the achievements of the "Made in China 2025" project and the expected industrial transformation will not be achieved across the country. Balanced development between different regions shall also be seen as the precondition for achieving the expected results in terms of industrial capacity.

¹⁰ Statistics from National Bureau of Statistics, 2015, 2016, 2017

- R&D

According to the World Bank, R&D expenditures have been made on creative work to increase knowledge, including knowledge of science, culture, and society, and the use of knowledge for new applications (World Bank 2006). The following Figure 4 demonstrates the R&D expenditure (% of GDP) in China from 2007 to 2017. As one could see from the data in the figure, the total R&D expenditure in China has accounted for over 2% of the GDP since 2014. Although there is still gap compared with OECD countries (2.4%), it has exceeded the average level of 15 EU countries (2.08%) (MIIT 2017). The government is taking efforts on supporting the R&D activities in universities as well as research institutes and establishing various R&D centers. Till now, a large number of R&D achievements, including passenger aircraft, new energy vehicles, biomedicine, etc. have already been put into use (MIIT 2016).

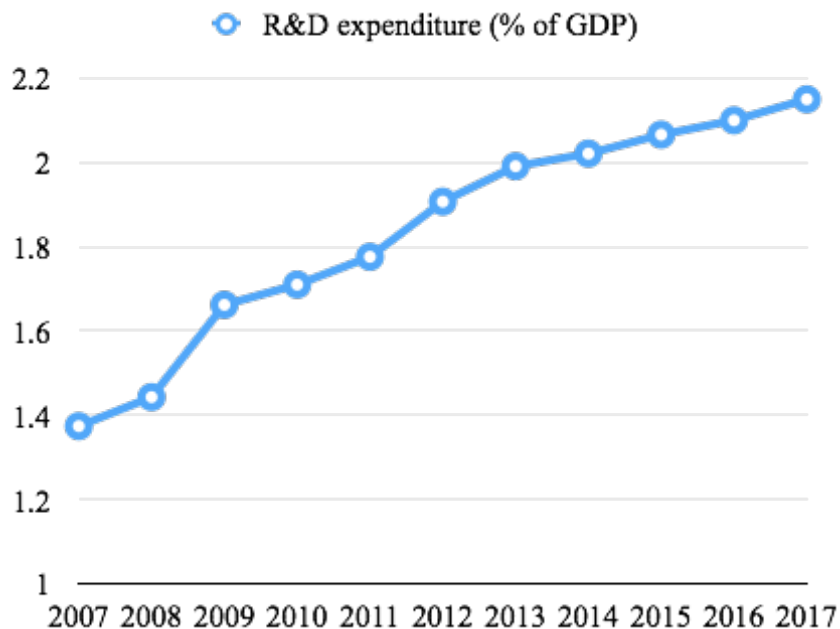


Figure 4. R&D expenditure in China from 2007 to 2017 (% of GDP)

Source: World Bank; National Bureau of Statistics

From the preliminary results of the “Made in China 2025” project in terms of R&D, it is clear that R&D shall be seen as the key focus of the project. Under the current trend, more public funds as well as private investment will be allocated in order to support the R&D activities. By supporting the R&D related activities, it will be helpful on enhancing the overall capacity of independent innovation of Chinese manufacturing industry. It could also be expected that China will be able to have more R&D achievements in the near future, especially in those key

industries of “Made in China 2025” project including ICT, high-end numerically-controlled machine tools and robotics, aerospace equipment, etc. Thus, it could be concluded that the R&D capacity in Chinese manufacturing industry will be significantly improved with the assistance of the “Made in China 2025” related policy initiatives.

However, for achieving the above positive results, large amount of financial support is not sufficient. High-quality R&D activities, effective government initiatives and reasonable allocation of public funds are required as well (Trajtenberg 2002; Feldman and Kelly 2006). The current enormous enthusiasm for R&D related activities could also lead to irrational investment or duplicate construction since the supervisory mechanism in China is insufficient and the central government does not have enough communication with regional government (Wübbeke et al. 2016; Zhang 2017). The Vice-Minister of MIIT Feng has also expressed his concern on the issue that the “Made in China 2025” project will lead to another round of duplicate constructions.¹¹ As argued by the specialists from MIIT (2016), some of the focused industries such as robotics, new materials, smart manufacturing, etc. have already demonstrated that subsidy gluts and tax reduction would often lead to overinvestment. As mentioned by Wübbeke et al. (2016), the efforts of local governments in terms of R&D related activities are often uncoordinated and redundant. Thus, the expected results regarding R&D activities would be achieved only when the above issues have been overcome.

- Economic growth

Manufacturing is supposed to be considered as the wealth-producing sector of one country and service sector consumes the wealth in contrast (Joseph 1976). Empirically, manufacturing industry has played important role on promoting the economic growth in many countries. Development on manufacturing-based strategy is an important part of promoting the economic growth in China and has various achievements during the past decades as well (Zhao and Li 1997). Since the implementation of “Made in China 2025” project, Chinese government is attempting to adapt a balanced model of economic development. While promoting the transformation and upgrading of the current manufacturing industry, government has also attached importance to the development of the tertiary industry. Also the government has taken effort on promoting the development of service-oriented manufacturing.

¹¹ Xinhuanet 新华网 (2015). “工信部:最担心‘中国制造2025’再现重复建设” (MIIT: biggest concern for ‘Made in China 2025’ are reappearance of duplicate constructions). December 28. http://www.nmg.xinhuanet.com/xwzx/kjww/2015-12/28/c_1117602798.htm. Accessed: July 11, 2016.

Figure 5 presents the GDP in China from 2007 to 2017; Figure 6 shows the changes in China's economic structure from 2007 to 2017.

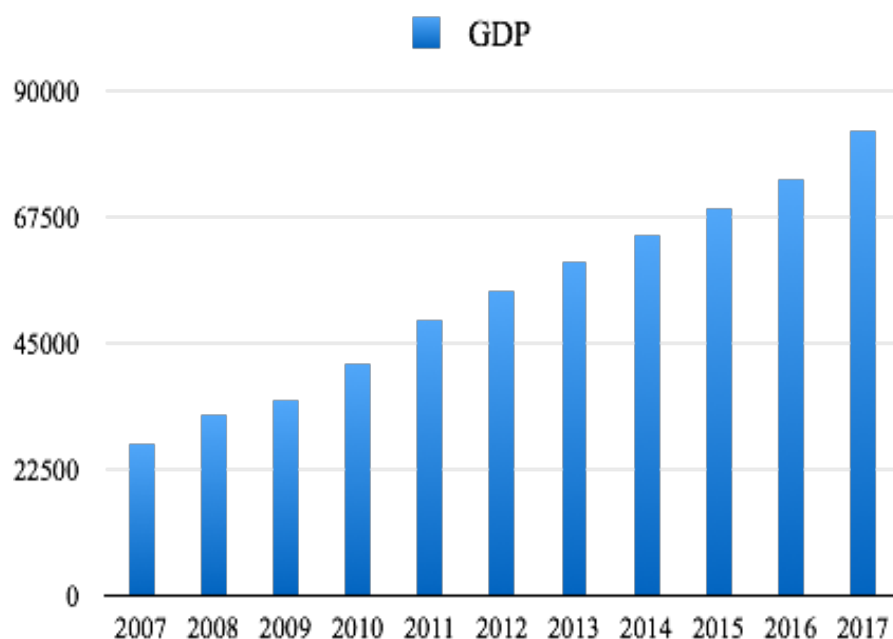


Figure 5. GDP in China from 2007 to 2017 (CNY, billion)

Source: National Bureau of Statistics

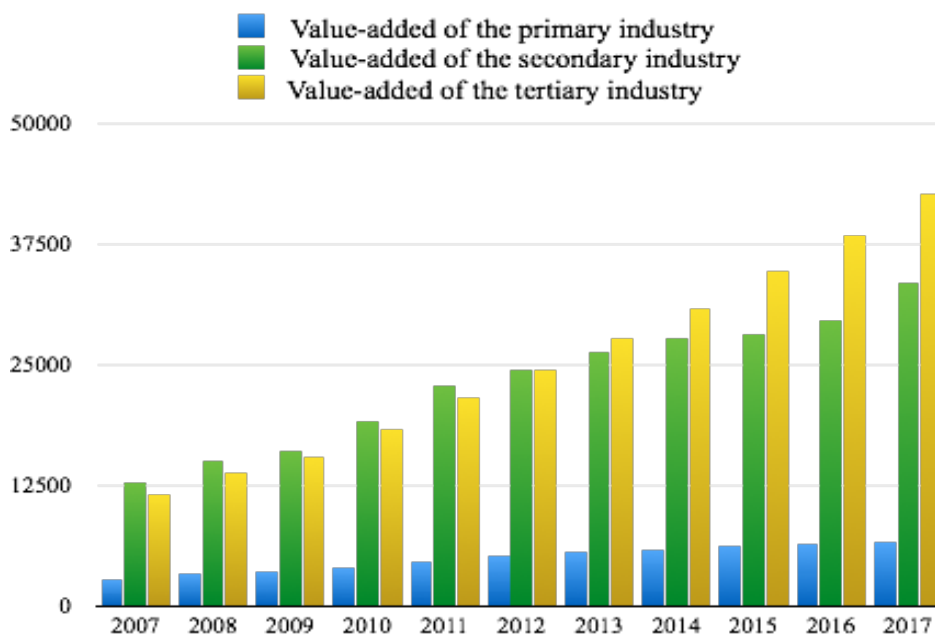


Figure 6. Changes in China's economic structure from 2007 to 2017 (CNY, billion)

Source: National Bureau of Statistics

In general, the implementation of the “Made in China 2025” project has already affected the economy in China and has gradually adjusted the current economic structure. According to the trends that presented in the above two figures, it could be predicted that China will still enjoy a strong GDP growth and steady economic development. Regarding the current economic structure, while the Chinese economy will still rely on the secondary industry (manufacturing industry) to a large extent, the role of tertiary industry (service industry) will become more and more important in the future. And due to the current trend of promoting service-oriented manufacturing in China, it could also be forecasted that the proportion of tertiary industry in the overall economy in China will keep increasing. According to Wen (2010) and Li (2015), China has gradually entered the period of post-industrialization, in which high-tech industries would play a leading role and at the same time the decline of traditional industries is unavoidable. Some traditional industrial zones such as Dongbei, Liuzhou, etc. are now suffering rapid decline and lacking the vitality of economic growth (Wen 2010). The decline of traditional industrial zones would result in the unbalanced economic growth across the country and affect the quality of economic development (Kahn 1999; Li 2015). Therefore, to secure a balanced and healthy economic growth, instead of promoting the R&D activities on high-tech industries, it is also important for the Chinese government to attach greater importance on helping those lagging areas to achieve their industrial transformation and upgrading.

In addition, traditionally foreign direct investment (FDI) tends to flow to the countries that have healthy economic conditions (Cheng and Kwan 2000; Stehrer and Woerz 2009). In a more macro perspective, since the Chinese economy has large volume and the trend of stable growth, it will also be able to have positive effect at the international level. The decent economic environment in China will be able to attract more foreign investment and therefore will promote not only the economic growth in China but also the global economic cooperation. Combined with the BRI project, “Made in China 2025” project and its spillover effects are expected to be able to inject more vitality to the global economy.

- Social structure

Last but not the least, “Made in China 2025” project would also promote the changes in the social structure in terms of population distribution in urban as well as rural area. The following Figure 7 demonstrates the population distribution in China from 2007 to 2017.

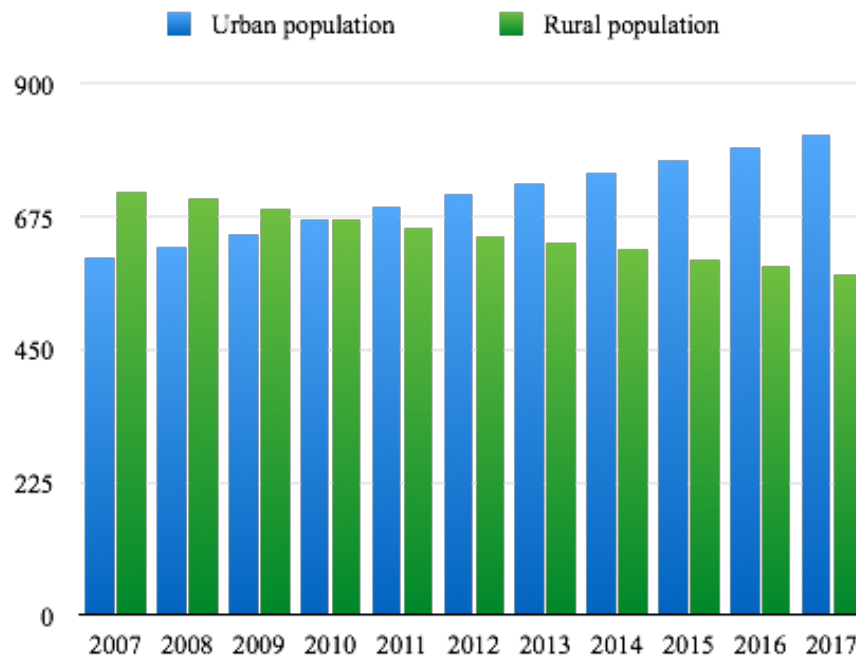


Figure 7. Population distribution in China from 2007 to 2017 (million people)

Source: National Bureau of Statistics

As could be read from the above figure, the urban population is gradually increasing, while in rural area the population has declined in recent years. The implementation of “Made in China 2025” project will be able to speed up the process of industrialization in China and the development of manufacturing industry will create more job opportunities. Thus, more rural population will pour into urban area and the process of urbanization will be accelerated. According to the statistics from National Bureau of Statistics, the current urbanization rate of China has reached 58.72% and the average growth rate has reached 1.4%.¹² Under such trend, it could be forecasted that during the early stage of the implementation of the “Made in China 2025” project, China’s urbanization process will enjoy a stable growth and will be able to exceed 60% by 2020.

Under such trend, it is also important for the Chinese government to be careful about the signs of over-urbanization in some cities such as Beijing, Shanghai, Guangzhou, etc. According to the experience of some Latin American countries, over-urbanization would result in several serious problems including unemployment, widening wealth gap, environmental pollution, security, etc. (Cohen 2006; Sun 2013). In order to secure a healthy social structure in China, reasonable city planning and effective population management mechanisms are required. At

¹² Statistics from National Bureau of Statistics, 2017

the same time, promoting the development of small- and medium-sized cities is also what the Chinese government should take into account. As suggested by Sun (2013), it would be able to release the pressure in the above cities that have shown the signs of over-urbanization. The rise of the small- and medium-sized cities would narrow the gap between different regions and would therefore have positive effect on the full realization of the expected results of “Made in China 2025” project.

4.2.3.2 Risk Factors

The positive results are often associated with several risks. According to the empirical findings as well as various related data that present the current situation and existing problems of the “Made in China 2025” project, the author focuses on some of the risk factors in terms of project planning as well as project implementation that could affect the final success of “Made in China 2025” project. The following 4 risk areas are not selected randomly. On the contrary, the following risk factors are determined in light of the Chinese national conditions including political environment, economic status, overall technological standards as well as regional development. And some of the in-depth mechanisms of the risk factors such as lacking efficient coordination mechanism, unbalanced regional development, etc. should even be seen as “typical Chinese problems” that have been existing for a long time (Yang 2015; Zhang 2017). Some of the risk factors have been mentioned by other scholars when carrying out similar analyses (see Wübbeke et al. 2016; Feng 2016; Huang 2017; Zhang 2017). By mapping these risk factors, it will make it easier for policy-makers to understand the most urgent issues that need to be solved in order to guarantee the final success of the project.

- Uneven development and lacking explicit coordination mechanism

Regarding the implementation of “Made in China 2025” project, one should notice that some relevant organizations and arrangements such as “*National Manufacturing Power Construction Leading Group*” as well as “*China Academy of Industry 4.0*” are already existing and would be expected to serve the purposes of information exchange, project implementation coordination in order to achieve a coordinated and balanced development of the current Chinese manufacturing industry at national level. However, for instance, it seems to be extremely difficult to ensure the same standard procedure and efficiency across the entire country since there is still huge gap between regions in terms of industrial capacity, economic growth, etc. (Kanbur and Zhang 2005; Huang 2017).

China is a large country which has the largest population in the world.¹³ Although Chinese government has been making efforts to narrow the gap between different regions since the official establishment of the country in 1949, the issue of the uneven development across the country has not been solved yet and the gap is very likely to become even wider (Kanbur and Zhang 2005). As could be read from the strategic plan of “Made in China 2025” project, there are 10 focused industries including ICT, high-end numerically-controlled machine tools and robotics, aerospace equipment, etc. Most of the industries concentrate on the process of equipment manufacturing and the related industrial basis for promoting the high-end manufacturing (MIIT 2015). However, these could not be the focuses for all the regions across China. On the contrary, each region should consider its own condition such as the economic situation and industrial basis in order to select their own focused fields and implementation approaches. In other words, the coordinated development of the manufacturing industries in different regions will not only affect the effectiveness as well as efficiency of the implementation, but also will determine the success of the project.

Till now, some regions have already put forward their own “Made in China 2025” implementation guidelines, but either from the perspective of focused industries or main tasks, they are quite similar as the original document of “Made in China 2025” project. For some cities such as Beijing, Shanghai and Guangzhou, which have already had advanced manufacturing industrial foundation and may have already entered the stage of “post-industrialization”, it would be possible to have a faster progress on achieving the proposed goals. For other regions that have relatively weaker economic and industrial foundation, it would be better to give priority to the development of advantageous industries based on their own conditions. As the general proposal of implementing “Made in China 2025” project would not be able to fit every city, local government should figure out individualized approaches rather than just copy the content from the documents that were published by the central government and ministries.

There is also another fact that could be used to explain the negative effects of the insufficient coordination mechanism. As China has already reached the mid-late period of the industrialization, a certain degree of excess manufacturing capacity is unavoidable. Driven by

¹³ Data from World Bank, 2016

the profit, local governments in many regions may tend to focus on the industries that have more potential profit and space for development. Indeed, competition at certain degree will be able to stimulate the growth of the specific industries. However, it would make the issue of excess manufacturing capacity more serious. In China, the performance of the central government on helping local government to avoid irrational behavior is not satisfied and communication between local governments in different regions is not sufficient (Yang 2015; Zhang 2017). Here, one could take the robotic industry, which is also one of the focused technical fields of the “Made in China 2025” project as an example. Till now, in many regions the R&D of advanced robotics has been carried out under government initiatives. According to the statistics from 2016, there are more than 800 robotics related enterprises and over 40 related research centers in China.¹⁴ There is no doubt that there would not be enough market need for so many related enterprises in this field, therefore it should be considered as inefficient overlapping construction with severe waste of resources as well as fiscal support. As mentioned before, the Vice-Minister of MIIT Feng (2016) has also expressed his concern on the issue.

The insufficiency of explicit coordination mechanism has resulted the current unbalanced development as well as the irrational planning of the manufacturing industry in China. So far, although Chinese government has put forward the white paper of “Made in China 2025” project and the “1+x” policy documents, the above documents are just overall instruction from a rather macro perspective. Ideally, central government shall act as a conductor or supervisor to support the local government to carry out reasonable planning for developing the manufacturing industry (see also Hendriks and Tops 1999). Also, for the implementation of policy initiatives, central government shall act as a consultant in order to help local government to avoid irrational behavior on investment, public procurement, resource utilization, etc. However, the current situation for implementing “Made in China 2025” project across China could not be seen as satisfied since effective and efficient coordination between central and local government is lacking. This risk factor has not only resulted in the problems that have been mentioned before, if one consider it in a long term vision, it is even likely to affect the final result of this project.

- Over-ambitious catch-all approach

¹⁴ Statistic from National Bureau of Statistics, 2016

The “Made in China 2025” project could be seen as one of the most ambitious Chinese policy initiative in the history. Even though China has been considered as the most competitive manufacturer in the world according to the report from Deloitte (2016), it was mainly because of the quantity rather than the quality. “Big but not strong” has been the main problem of Chinese manufacturing industry for a long period and China has never become a world manufacturing power like the US or Germany in its history. Stimulated by the “Industry 4.0” project of Germany and the “reindustrialization” process in the US, China put forward this “Made in China 2025” project, which is even seen as the “Chinese Industry 4.0” (Ren 2015; Li 2017). However, this project seems to be over-ambitious without comprehensive consideration of China’s own situation.

Compared with Germany who has already had advanced industrial foundation, China still has a huge gap to overcome before being a world power of manufacturing (Ren 2015). As mentioned before, China has a giant landscape and the industrial development in different regions is varying. According to the ideas of “Industry 4.0”, the history of manufacturing industry shall be divided into 4 stages from “Industry 1.0” to “Industry 4.0” (BMBF 2013). Unlike in Germany where a large amount of the manufacturing enterprises have already reached the stage of “Industry 3.0” and currently are under the transformation to “Industry 4.0”, in China one would be able to find manufacturing enterprises that range from “Industry 1.0” to “Industry 3.0” (MIIT 2015). In general, the low-end manufacturing still occupies a relatively large proportion in China. The uneven development of Chinese manufacturing industry across the country has determined that for most of Chinese manufacturing enterprises the most urgent task is to firstly reach the stage of “Industry 3.0” where the electronics and ICT shall be widely applied to the entire process of manufacturing.

As has also been argued by Wübbecke et al. (2016), “Made in China 2025” applied the top-down approach with enormous mobilization capacity that would lead to an over-ambitious catch-all project whose related policy initiatives do not meet the real need of enterprises. Chinese government imposes the priority of smart manufacturing on the domestic enterprises without considering their actual circumstances. In China, since there are too many manufacturing enterprises that are barely automated and some of the enterprises should even be seen as the handicraft workshops, it is obvious that they are not prepared for applying the advanced technologies such as CPS, AI, or Big Data that required by the concept of “Industry 4.0” at this moment to catch the current trend. Chinese policy-makers tend to focus on the

most advanced technologies during the project implementation since the final goal for China is to become a world leader in high-end manufacturing. However, disregarding the urgent need to upgrade to basic automation and digitalization will probably lead to a disappointing result.

In addition, given the selected technologies for breakthrough, China is also facing the risk of not being able to achieve the desired results in all the focused technological areas (Wübbecke et al. 2016; Li 2017). According to China's plan, the government is expecting to maintain leadership worldwide in all the ten fields, including aerospace technology, new energy vehicles, rail transportation equipment, etc. (MIIT 2015). Indeed, for some of the focused industries the technical standard of China has already become advanced and leading in the world. But in order to cover all the focused industries and receive positive results, it is necessary to have an explicit coordination mechanism of all the involved actors and a powerful industrial foundation. As mentioned before, those are what China is currently lacking.

Since "Made in China 2025" project was launched in 2015, China has worked very hard in order to achieve its goals and many technical breakthroughs, while positive results have already been achieved. For example, the applications of ICT and automation application in Chinese manufacturing industry are under stable growth, and various high-tech products through independent R&D including passenger aircraft, supercomputer and telecommunication technology have gone into service (State Information Center 2016, 2018). However, the project has not completely changed the overall situation of Chinese manufacturing industry so far – many core technologies still rely on other countries to a large extent; many of the China's related enterprises are still at the bottom of the global value chain in terms of labor division (Ren 2015; Wübbecke et al. 2016). Thus, the author believes that the main tasks as well as the focused technological fields of "Made in China 2025" project are over-ambitious without clear understanding of the current situation of Chinese manufacturing industry and the need of related enterprises.

- Lacking qualified talents

During the past 3 decades, the "farmer workers" or migrant workers in China have been served as flexible low-cost labor force that has effectively promoted the rapid growth of Chinese manufacturing industry (Li 2017). However, since China has adjusted its

manufacturing strategy that would focus on high-tech as well as high-quality products, more educated technical talents are needed. According to the statistics from National Bureau of Statistics and the Ministry of Human Resources and Social Security, Chinese technicians with national qualification account for less than 5% of the total employed population.¹⁵ This is in marked contrast to the situation in Germany, where more than 60% of the technicians have obtained qualification certificate and around 20% of them also have strong academic background.¹⁶ Although China has a large amount of human resources, it is still facing challenge on providing qualified manufacturing talents in order to promote the transformation towards “smart manufacturing”. Lacking qualified human resources in face of the current transformation towards “smart manufacturing” shall be considered as another risk factor of “Made in China 2025” project.

The implementation of “Made in China 2025” project requires more technical talent that can adapt to the deep integration of ICT and manufacturing technologies and the project has also stressed the goal of establishing multi-level education system in the face of the issue. However, the current talent supply mechanism is still not being able to meet the demand and related policy initiatives could not achieve the expected results. The in-depth reasons of this issue could be elaborate as follow. Firstly, the higher education system has not escaped the impacts of previous “Soviet model” yet and is not be able to serve the growing need of the new industrial revolution (Ding and Zeng 2015). The higher education in China tends to focus more on the theories rather than practice, and the cooperation between universities and enterprises is insufficient. This has resulted in the unbalance between the demand and supply of human resources. Secondly, China’s vocational education system is relatively backward compared with other developed countries. Although the government has put forward the task for optimizing the vocational education and has already achieved some impressive progress, there is still gap towards other developed countries. The insufficient cooperation between colleges and enterprises and unsatisfactory quality has limited the development of vocational education in China (Lian and Guo 2016). Thirdly, the salary as well as social status of manufacturing technicians need to be improved. According to the statistics in 2016, the average annual income of manufacturing industry was CNY 59470 and it has been experiencing a stable growth since 2007.¹⁷ The average annual income of manufacturing

¹⁵ Statistics from National Bureau of Statistics and Ministry of Human Resources and Social Security, 2016

¹⁶ Statistics from Federal Ministry of Labor and Social Affairs, 2016

¹⁷ Statistics from National Bureau of Statistics, 2016

industry is slightly higher compared with the average annual income in China (CNY 57394).¹⁸ However, the overall income of manufacturing industry is still at a relatively low level compared with other industries and the price inflation in China. This unreasonable income status has led to the loss of large amount of manufacturing talents and university graduates are no longer willing to join the manufacturing industry. Also, influenced by the Chinese traditional culture, the social status of manufacturing technicians is relatively low, which has decreased the enthusiasm for young generation to choose manufacturing-related professions (MIIT 2017).

Although “Made in China 2025” project has announced the importance of establishing a high-quality multi-level education system in order to serve the increasing demand of technical talents in manufacturing industry, the existing weaknesses in the current Chinese education system have influenced the process in a negative way (Ding and Zeng 2015; Lian and Guo 2016). As has been argued by the specialists from MIIT (2015) and Li (2017), talent shall be considered as one of the key factors that could have huge impact on the final success of “Made in China 2025” project. However, related policy initiatives have not offered detailed guidelines on how to improve the current education system in terms of the above issues. Thus, the author’s point is that if the education system in China could not achieve huge improvement within 2 to 3 years, China will still face the risk that lacking sufficient technical talent will not support the R&D process of focused technologies and the digital transformation in current manufacturing industry.

- Allocation of public funds

The inefficient allocation of public funds shall also be seen as a risk factor that would affect the final result of “Made in China 2025” in a negative way. In order to support the implementation of “Made in China 2025” project, Chinese government has increased the amount of financial support for the manufacturing enterprises. According to the data from the Ministry of Finance, the public expenditure on supporting “Made in China 2025” project has reached CNY 0.73 trillion and taken up 1.5% of the GDP in 2017. It has increased by 11% compared with last year and has taken up more than 3.5% of the total public expenditure.¹⁹ If one considers the amount or percentage of public funds, China has significantly injected a

¹⁸ Statistics from National Bureau of Statistics, 2016

¹⁹ Statistics from Ministry of Finance, 2017

huge amount of money on promoting the project. However, the massive funds are associated with misallocation of public money without effective supervision mechanism.

Influenced by the “official-cored idea” in China, the enterprises, which can receive funds are usually those that have close connection with the public sector rather than those that are innovative and efficient (Zhang 2017). For example, according to the interview that was conducted by Wübbecke et al. (2016) with the staff from a Chinese electronics enterprise, the enterprise has secured public funds for a pilot project due to its tight connection with the government by hiring a former official of MIIT. Also, in the robotics industry one could also be able to find instances of rent seeking activities in some of the enterprises as well as misappropriation of the public funds that were actually prepared for supporting innovation activities (Feng 2016). The above examples are just the tip of the iceberg for such kind of problems. Although the reform on the financial system in China has already achieved positive results, due to the lacking of efficient and rational financial supervision mechanism, the issue of inefficient use of public funds has not yet been completely solved.

The inefficient allocation of public funds would also have negative impact on the implementation of “Made in China 2025” project. Regarding the current situation, it will lead to the waste of financial resources. In a longer run, it will also hurt the enthusiasm of the manufacturing enterprises that really have the intention to carry out innovation activities but could not be able to receive sufficient public funds and will therefore have negative influence on China’s overall capacity of independent innovation.

4.3 Policy Recommendations

Based on the previous empirical research, it would be possible to put forward several potential suggestions in order to enhance the effectiveness as well as efficiency of “Made in China 2025” project.

- Enhance the coordination mechanism between central and local government

As mentioned before, lacking sufficient coordination has resulted in the irrational activities of local government and the waste of resources. Thus, it would be better if the central government would provide necessary guidance for the regional government according to the distinct industrial conditions in different regions in order to avoid the phenomenon of unreasonable planning and duplicate construction during the implementation of “Made in

China 2025” project. For example, organizing related lectures as well as workshops for local governments to have better understanding of the project and acquire sufficient related knowledge; or sending specialists to different regions in order to serve as the consultants to assist local government in terms of policy planning and implementation. At the same time, local governments shall also actively communicate with central government in order to promote effective information exchange. According to the experience of Germany, although local governments have the autonomy to a large extent, the cooperation between central and local government is still very close (Hendriks and Tops 1999). China should also enhance the coordination mechanism between central and local governments in order to support the implementation of “Made in China 2025” project.

- Narrow the gap between different regions

The uneven regional development has been one of the key reasons that have hindered the overall development of Chinese manufacturing industry for a long while. Although it is extremely difficult to completely solve this problem, Chinese government should try to minimize the gap between different regions. For those regions with relatively weaker industrial foundation, more public funds should be injected in order to enhance the basic industrial as well as innovation capacity. At the same time, it would be good if more R&D centers or innovative manufacturing enterprises could be located to those regions rather than to those well-developed first-tier cities in order to promote the technological standards and boost the economic growth. Also, it is important to help those regions to attract more qualified talents as well as labor force. The government could put forward various preferential policies in terms of subsidy, social security, education as well as training in order to encourage more people to move to those regions. By narrowing the gap between different regions through various approaches, it will be able to improve the overall performance of Chinese manufacturing industry and promote the balanced progress of “Made in China 2025” project.

- Strengthen the national supervisory mechanism

Since Chinese government has injected quite large amount of fiscal support on the “Made in China 2025” project, efficient allocation of the public funds is also essential. As mentioned before, China’s inefficient allocation of public funds would result in negative effects during the project implementation. Therefore, instead of providing sufficient fiscal support, government should also try to strengthen the national supervisory mechanism. Related law as

well as regulation should be optimized in order to serve the current need of an effective and efficient supervisory mechanism. It would also be useful to set up special financial supervisory working group for evaluating whether the enterprises should receive funds or not and make sure that the funds are used for the right purposes. In addition, the enterprises that receive fiscal supports shall have the obligation to report to the working group regularly about the usage of received funds in detail and the latest progress of the innovation activities. By doing so, it will be able to improve efficiency of the allocation of public funds and therefore have positive effects on promoting the implementation of “Made in China 2025” project.

- Enhance the application-oriented education

Last but not the least, Chinese government should also take effort on enhancing the education of technical professions. For the implementation of “Made in China 2025” project, China does not only need scientists, but also demand more skilled technical professionals. According to the successful experiences of Germany, the role of application-oriented universities as well as vocational education institutes shall not be ignored (Taylor et al. 2008). Therefore, in Chinese case, more efforts should also be taken on the optimization of current non-university education system. Not only the quality of education shall be improved, but also there is a need to establish more intensive cooperation with related enterprises. At the same time, the government should enhance the publicity of the non-university education in order to help those schools to obtain more qualified students. The improved application-oriented education would be helpful on providing qualified human resources in support of the upgrading and digital transformation in current manufacturing industry in China.

5. Conclusion

The aim of the current MA thesis is to make an analysis on the innovation policies in China under the background of “Industry 4.0”. The theoretical framework of the current thesis is based on the innovation policy framework that was put forward by Rothwell and Zegveld (1981, 1984) and various concepts as well as theories of public policy analysis and evaluation (see Dunn 1981; Rossi et al. 2003; Zhu et al. 2015). The empirical part has presented a case study of the “Made in China 2025” project in terms of policy framework, likely consequences, and risk factors. At the same time, the author has put forward several potential policy recommendations.

Based on the empirical research, the author has concluded the following arguments. Stimulated by the idea of “Industry 4.0” and the re-industrialization in other countries, “Made in China 2025” project was put forward in 2015 with various related public policies. Regarding to the content, the “Made in China 2025” project is similar to Germany’s “Industry 4.0” project to a large extent and has also covered all the 3 dimensions of the policy framework by Rothwell and Zegveld (1981, 1984). After two years’ implementation, the project has already achieved various positive results and it could be forecasted that this project would be able to have more contribution in terms of industrial capacity, R&D, economic growth, and social structure in the future, if several preconditions could be fulfilled. However, the above achievements are also associated with several risks factors that may also affect the final success of “Made in China 2025” project. The project seems to have adapted over-ambitious approaches without considering the current situation of Chinese manufacturing industry and the real need of the related enterprises. The uneven regional development, the insufficient coordination and supervision mechanism, and the lacking of qualified technical talents would affect the final result of “Made in China 2025” project in a negative way.

Based on the above empirical findings, the author has therefore put forward several policy suggestions with regard to the policy implementation. In general, for the future

implementation of the “Made in China 2025” project, a more coordinated as well as balanced development model should be adapted in order to secure the effectiveness and efficiency of the related innovation policies. By carrying out this research, the current thesis will not only fulfill the gap in the existing scholarly works, but will also be able to open up possibilities for further researches and establish more concrete hypotheses.

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APPENDICES

Appendix 1. “1+X” Policy Documents of “Made in China 2025” Project

- Main strategic document: *Made in China 2025*
- 11 supportive policy documents
 1. *Implementation Guideline for Manufacturing Innovation Center Construction Project*
 2. *Implementation Guideline for Enhancing Industrial Foundation*
 3. *Guideline for Implementing “Smart Manufacturing”*
 4. *Guideline for Implementing “Green Manufacturing”*
 5. *Implementation Guideline for High-end Equipment Innovation Project*
 6. *Special Action Guide for Developing Service-oriented Manufacturing*
 7. *Guideline for Developing Pharmaceutical Industry*
 8. *Special Action Guide for Promoting Product Quality in Equipment Manufacturing*
 9. *Guideline for Manufacturing Talent Development*
 10. *Guideline for Developing New Material Industry*
 11. *Guideline for Developing ICT Industry*